Chapter 4 Ecological panel based on plastic aggregates, natural fibers, and plaster

Capítulo 4 Panel ecologico a base de agregados plasticos, fibras naturales y yeso

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Abstract

Today, there is a growing need for alternative construction technologies that allow, among other things, to reduce of plastic waste and energy consumption during the life cycle of buildings. In this context, this article presents the partial results of a research project whose objective is to develop an innovative solution for plasterboard with plastic aggregates such as pet and Ixtle natural fibers. This solution is based on a plasterboard made with a mixture of eco-efficient composite materials. The composite material used in the production of the plates or panels results from the combination of two industrial by-products: commercial plaster; crushed or laminated pet, and natural "ixtle" textile fibers resulting from the "carving" process of the maguey leaves. In addition to the raw materials, the innovation of the solution also results from new future proposals for experimentation with different recycling materials. In this work, details of the process of elaboration of the plates and both the optimization of the composition of the material and the construction technology are provided, within the long strategies, the tests and validation of the mixtures will be carried out for the elaboration of plates from the point of view of mechanical, thermal and acoustic behavior, which from the results obtained can be concluded in the feasibility that meets all the structural stability requirements suitable for this type of construction element.

Panel Ixtle, Innovation, Experimentation

Resumen

Hoy en día, existe una creciente necesidad de tecnologías de construcción alternativas que permitan, entre otras cosas, reducir los residuos plásticos y el consumo de energía durante el ciclo de vida de los edificios. En este contexto, este artículo presenta los resultados parciales de un proyecto de investigación cuyo objetivo es desarrollar una solución innovadora para placas de yeso con agregados plásticos como el pet y las fibras naturales de Ixtle. Esta solución se basa en una placa de yeso realizada con una mezcla de materiales compuestos ecoeficientes. El material compuesto utilizado en la producción de las placas o paneles resulta de la combinación de dos subproductos industriales: el yeso comercial; pet triturado o laminado, y fibras textiles naturales de "ixtle" resultantes del proceso de "tallado" de las hojas de maguey. Además de las materias primas, la innovación de la solución también resulta de nuevas propuestas de futuro para la experimentación con diferentes materiales de reciclaje. En este trabajo se brindan detalles del proceso de elaboración de las placas y tanto de la optimización de la composición del material como de la tecnología constructiva, dentro de las estrategias largas se realizarán las pruebas y validación de las mezclas para la elaboración de placas desde el punto de vista del comportamiento mecánico, térmico y acústico, lo que de los resultados obtenidos se puede concluir en la viabilidad que cumple con todos los requisitos de estabilidad estructural adecuados para este tipo de elemento constructivo.

Panel Ixtle, Innovación, Experimentación

1. Introduction

Betting on new construction materials that are friendly to the environment has led higher-level educational institutions, whether universities or technology, the construction industry, and all those actors involved in architecture to encourage students and researchers to reflect on the architecture commitment. And the impact of its architectural work on the natural or artificial context that surrounds it, as well as its influence on one of the most critical problems of humanity such as the climate crisis which includes climate change, the deterioration of farmland, the expansion of the urban sprawl, pollution and loss of biodiversity, it is necessary to understand and measure the responsibility of all these actors. That is, why it is essential to promote, analyze, innovate and experiment with new products for this great industry that is construction, but above all to look for new strategies for teaching architecture to make future architects aware of this great crisis, but above all as an agent generator of well-being with responsibility and social commitment. (see figure 1)

Figure 1 The Great Crash

Source (De la Madrid & Landeros, 2020)

One of the great concerns is the impact generated by these current construction products produced with renewable and non-renewable materials, their management and final disposal is a critical situation, which worsens as cities grow.

This article invites reflection and presents a research project developed from the classrooms of the degree in Architecture, which is mainly based on the elaboration of an ecological panel based on plaster and aggregates such as PET and ixtle as a constructive element. , with the use of natural materials such as maguey with its Ixtle fibers typical of the northern region of the state of Mexico, one of the objectives of the project is to verify its feasibility and effectiveness and thus be able to use them in construction as another alternative construction element, friendly to the environment and the use of this natural fiber and the recycling of PET.

Gypsum panels or commonly called in Mexico Tablaroca are generally composed of a center of plaster gypsum, cellulose and confined under pressure between two sheets of recycled paper, in Mexico there are in the current market, brands such as Tablaroca, Panel Rey, and Plaka Comex, among others, which within their characteristics have a good ecological balance due to their efficient use of raw materials, such as plaster and cellulose in the production process, within the construction sector they are commonly used for their excellent, acoustic and thermal insulation properties and its resistance to fire, in addition to its easy handling and flexibility.

However, although gypsum and cellulose are the natural raw material that is found in abundance, they must be treated as non-renewable materials to be aware of their care, which is why this proposal to make the prototype of the panel of plaster, is from the analysis of conventional or commercial plaster panels which the elaboration of the panel will be carried out a controlled production process from the selection of the material and the processing of the material such as Ixtle and PET, and thus by uniting these two elements to obtain a more environmentally friendly and sustainable product, an element with these characteristics will allow the construction sector to reduce the rate of pollution released during its practice, it will be a resistant and light element, which will serve within the design and construction of the interior space.

That is, why the reason for this research, it is of the utmost importance to be aware of the architectural work and one of them is the interest in creating innovative projects, benefiting a large part of society, based on the above, it was decided to propose the project called "Ecological plasterboard based on PET plastic aggregate and ixtle", to generate a sustainable ecological material using materials that reduce the impact on the environment, and have benefits such as fire resistance, acoustic insulation, thermal resistance to humidity, at a low cost in its production and thereby contribute to reducing pollution, global warming, and environmental impact. (Acosta, 2009)

Under this perspective, it is evident that the architect's profession, originally so linked to the land, has been modified in recent times due to social, political, economic, and educational changes, the introduction of new materials and new practices, today, it is done It is necessary to propose awareness programs aimed at architecture students where they reflect on priority issues such as in this case, the shared responsibility with the great environmental problems, and as far as possible, the social co-responsibility that joint participation requires, coordinated and differentiated from producers, distributors, consumers, users of by-products, and from the three levels of government as appropriate, under a scheme of market feasibility and environmental, technological, economic, and social efficiency.

2. Developing

The consumption of plastic materials has increased notably in recent years worldwide, specifically PET (Polyethylene Terephthalate) due to the proliferation of containers of this material in the food industry. PET containers have added to the changing consumption habits of the population such as consuming more and more bottled water and carbonated drinks, which leads to producing more waste because the container has no useful value for the consumer. and that is why what continues to contribute to the contamination of the soil and water is discarded. (Cristian, et al 2003)

When PET is discarded, its disintegration effect is for a long time. According to calculations, it can take between 500 and 1000 years to decompose. And even if it stops being seen, it will have released thousands of micro PET fragments that are even more polluting. Currently, there must be sustainable materials that help minimize pollution on the planet, especially those materials that are used in the field of construction. (Hernández, 2008)

Innovation in new materials provides construction with the fluidity to build, in addition to the fact that architecture itself is increasingly focused on the use of sustainable materials that have a favorable impact on the environment and the economy of consumers. Such is the case of gypsum boards or panels that minimize time and costs when building and designing exterior and interior spaces, where the general purpose of companies is to seek short-term alternatives to increase their productivity.

However, it can be counterproductive when it comes to being transported and manageable for assembly since they can become heavy and fragile. These panels are mainly made up of plaster, cellulose, water, and cardboard. Gypsum is a natural and universal raw material that is found in abundance in nature and its residues are biodegradable, however, care must be taken for it. For this reason, it is proposed to make a plaster panel mixed with PET grinding, this is one of the most common wastes currently causing a notable acceleration of global warming and great pollution in rivers, seas, oceans, forests, etc.

PET offers high resistance, a good barrier to CO2 and humidity, is compatibility with other materials, is recyclable, low weight, and waterproof. That is, why it has been chosen as one of the materials that will be most present in the elaboration of the panel. In addition, it is decided to add a vegetable fiber (Ixtle) obtained from the maguey that will allow a panel with greater resistance, since this fiber is placed on the lateral faces of the panel providing greater rigidity. (Alesmar et al, 2001)

The composition of the chosen materials allows us to achieve a sustainable element that will be used to create interior spaces seen mainly in walls, ceilings, ceiling.

The research topic called "Ecological plasterboard based on PET plastic aggregate and ixtle" was selected according to the current problem of environmental pollution where plastic is one of the main wastes found in large volumes in different places. That is, why it is decided to reuse I, so that the pollution it generates by having a late degradation process in the environment can be avoided. Being thus an idea of innovation that seeks for our current quality of life and that of future generations.

The panel is made with plaster, recycled PET plastic, and ixtle, which includes the grinding of PET, this being a process that will convert the bottles into smaller particles until reaching the granulometry required for our product. Elaborating an element with these characteristics will allow the construction to reduce the rate of contamination that it releases during its practice, it will be a resistant and light element, in addition to having an accessible price for the public that will serve the interior design of spaces where it is necessary to divide or build a space in creatively ways with the best finish.

For this, the appropriate execution of recycling and the implementation of concrete actions that benefit ecological, economic, and accessible aspects to a large part of humanity is essential.

The composition of the mixture of these materials proposes to obtain a sustainable element that guarantees the reduction of pollution and has unique characteristics of resistance and durability as an alternative to be used in the construction of interior spaces in dividing and decorative walls, false ceilings, and furniture, among others, other uses, depending on the required need of the project to be implemented.

The materials that make up the innovative product are: plaster, grinding of PET plastic, ixtle, cellulose, and recycled cardboard. Gypsum is usually white, with a fine texture and low hardness. It is composed of crystallized calcium sulfate with two water molecules; It is obtained by calcination of hydrated calcium sulfate. Gypsum by itself does not have direct applications, however, it is a binder that hardens quickly. Its elasticity allows us to easily model various ornamental elements at a low cost. (Mayor, 1977)

Plastic grinding has properties that make it transparent, shiny, resistant to wear, has a good slip coefficient, is a good thermal barrier, against gases and moisture, etc. Its advantages include transformation through extrusion, injection, and perform blow molding, and thermoforming processes. (Cosmos O., 2021).

Recycled paper is a raw material that has a lower impact on the environment since its production represents a reduction of up to 60% in carbon dioxide emissions compared to other materials. It is cellulose, its decomposition time is short, in addition to the fact that, after recycling, recycled cardboard or paper does not lose quality or properties and is also cheaper. (London T., 2011).

And finally, the lechuguilla fiber (Ixtle) or Tampico fiber, as it is known internationally, has excellent quality due to its hardness, high strength, and durability given its high-water absorption capacity (65%) and its resistance to solvents, chemicals, heat, diluted and concentrated acids, abrasive products, petroleum distillates, alcohols, and vegetable oils. (Castillo et al, 2013)

3. Methodology

The research method is quasi-experimental, it is shown through the management of unproven experimental variables, in relatively controlled conditions, since being an experimental work where the participation of students is included to promote research, creativity, and innovation, but above all, raise awareness of major issues such as sustainability. Likewise, it is proposed to manage this research in three stages in the short, medium, and long term so that there is continuity both in the work and in the participating students during these periods.

The objective of this research is to study the feasibility of the module or construction element from something already created such as the plaster panel and its incorporation of PET and Ixtle fibers, which these elements will first undergo various tests, elementary physical in this way to know and demonstrate its physical properties, in addition, its comparison with similar elements, which will enable the detection of virtues or defects of the element, as well as the exploration of new forms of construction to detect its advantages in use, functionality, and sustainability within drywall standards.

Within the research strategies:

Short term

- Documentary and field research stage.
- Analyze information collected both bibliographic and field.
- Analyze and characterize existing and/or commercial prototypes.

Medium term

- Select plastic materials especially PET and recycled paper
- Select the plants for the elaboration of the Ixtle.
- Execute the experimentation of the materials to be used, as well as define the samples and the proportions with the plaster, PET, and ixtle.
- Submit to non-specialized conventional tests of the materials and the construction element (prototype),
- Analysis of results.

Long-term

- Determine the construction processes.
- Real-scale prototyping
- Submit the prototypes to specialized laboratory tests in terms of resistance and compression
- Compare the costs of the product in the current market.
- Analyze the function, resistance, and durability of the prototype.
- Identify the benefits of manufacturing ecological panels such as cost reduction and their functions.
- Integrate the ecological gypsum panel into the construction market, to achieve national recognition of the product.

4. Results and discussion

Experimental part

Next, part of the research strategies in its medium-term stage consists of the process for the preparation of the panel is described.

- The selection of plastic materials, especially PET, plaster, ixtle, and recycled paper
- Raw material manufacturing process.
- Execute the experimentation of the materials to be used, as well as define the samples and the proportions with the plaster, PET, and ixtle.

Materials

For the elaboration of the panel, a controlled production process will be carried out from the selection of the material and the processing of the materials.

PET plastic (*polyethylene terephthalate, polyethylene terephthalate, polyethylene terephthalate, or polyethylene terephthalate*), was chosen because we consider it the most common waste recorded daily.

In general, this material is characterized by its properties such as purity, high resistance, and toughness, it also has properties of transparency and chemical resistance; It is light, with high rigidity and hardness, as well as being recyclable. Through this last property of "recycling", we obtain the grinding through a process of cleaning and selecting the plastic so that it passes through a plastic materials mill where particles of between 4-10 mm are obtained.

This material will be used as mentioned before to obtain a granulometry or laminar product according to its properties, in order to integration with the plaster feasible, and ixtle to make the mixtures and able to form panels of 0.60 x 0.60 m and 12mm in diameter. Thickness according to NMX-C168-1977 "gypsum boards or blocks for interior walls" in section 5.4.

Figure 2 Pet

Source (Authors, 2022)

Gypsum (*calcium sulfate hemihydrate*) is originally a mineral called gypsum or gypsum stone. This rock is mainly made up of calcium sulfate with two water molecules (CaSO42H2O), called calcium sulfate dehydrate. From this mineral, you can obtain a product called calcium sulfate hemihydrate (CaSO4 1/2H2O), also known as construction plaster. In this form it acquires the ability to set in the air, it has properties such as malleability, hygroscopic, and favorable thermal conditions for construction (Mayor, 1977).

The ixtle, a material that is obtained through the "carving" of the maguey leaves (Salmiana), the integration of this natural material, arises by offering more resistance to the panel, forming a protective mesh on its lateral faces as it is a plant predominant succulent in several areas of the State of Mexico, it will allow us to access with greater accessibility and make use of the plant, manually obtaining the ixtle according to the ancestral technique to take advantage of this natural fiber. (Castillo et al, 2013)

Figure 3 Maguey Salmiana

Source (Authors, 2022)

Recycled paper

Recycled paper, also called post-consumer waste, carries a process to obtain cellulose, which is a pulp extracted from wood from chopping until it is transformed into a paste or pulp, which is subjected to chemical processes where cellulose is Obtained pure cellulose fibers, the Kraft paper process is based on a solution of sodium sulfide and sodium hydroxide in a 1:3 ratio for 2 to 6 hours at a temperature of 160 to 170 °C at the boiling point and that subsequently the sodium sulfide is eliminated (Budjiashvil, 2019)

The use of Kraft Paper has been considered since it is very resistant, and the paper guarantees stability between the composition of the materials that are part of the core of the panel. It can be said that this type of paper is integrated to give life to some multilayer materials since it is feasible to be combined with other diverse materials.

For the selection of these materials, it was possible to identify advantages and disadvantages of the requirements that could meet the technical properties, such as resistance, wear, absorption, and resistance, to be used in the panels, properties that would make it possible to build a panel with ecological characteristics and constructive.

Experimental part

The raw material manufacturing process

Obtaining PET plastic milling

a. PET collection (figure 4). It is the most conventional type of plastic in our daily lives, so it is very easy to get it, you must ensure that the material is free of impurities or dirt.

Figure 4 Plastic bottles

Source (Authors, 2022)

b. Cleaning of the collected PET material, in order to obtain a clean grinding of dirt that may affect the elaboration of the panel. If necessary, the PET will have to be washed to remove any type of contaminant. Here are the labels, caps, and mouth of the bottles that have been collected are also removed as seen in figure 5.

Figure 5 Removal of labels and caps from the collected bottles

Source (Authors, 2022)

c. Reduction of the size of the plastic through a mill where particles between 4 mm and 10 mm will be obtained. Figure 6 shows how the plastic bottles enter the plastic materials mill. And figure 7 shows the expulsion through the output chamber of ground plastic.

Figure 6 Entry of bottles to the hopper of the plastic materials mill

Source (Authors, 2022)

Figure 7 Expulsion through the output chamber of ground plastic

Source (authors, 2022)

d. A series of factors must be considered to obtain the grinding of plastic for verification of the desirable granulometry, once it is subjected to the grinding process, sieves must be used which will allow classifying the different sizes of plastics that were obtained, or, where appropriate, repeat the grinding process to obtain the appropriate granulometry for mixing with the materials used in the panel. (see figure 8)

Figure 8 Obtaining plastic milling for panel use

Source (authors, 2022)

Ixtle extraction

a. The process for obtaining the ixtle is described below, first, a maguey stalk is cut, using a saw bow and gloves, since care must be taken because the sap causes an allergic reaction on contact with the skin such as itching, or redness. (see fig.9).

Figure 9 Cutting of the maguey stem to obtain the ixtle

Source (Authors, 2022)

Subsequently, the sap is removed from the maguey fiber with the help of a stick or wooden trunk to obtain the ixtle, as shown in figure 7.

Figures 10, 11, and 12. The sap is removed to see the vegetable fiber, which is what is wanted.

Source (Authors, 2022)

Once the sap has been removed from the fiber, as shown in figure 13, all the fiber obtained from the maguey is left to dry in the sun for a period of approximately 3 to 4 days.

Figure 13 The ixtle is dried in the sun

Source (Authors, 2022)

Finally, when the maguey or ixtle fiber dries (figure 14,15), it can be used to make the panel.

Figures 14, 15. Ixtle fibers

Source (Authors, 2022)

Preparation of mixtures

The experimentation of the first mixtures was carried out to analyze the behavior of the materials among themselves and a 60 x 60 cm mold built with plywood and ¾ x ½ "wood strips was taken as a base, for the emptying of the mixtures.

Which were the following:

Table 1 mixture dosages

Materiales	Unidades	Mezcla 1	Mezcla 2	Mezcla 3
Water	mililitros	500	750	1000
Gypsum	gramos	500	750	1000
PET	gramos	250	300	500
Ixtle	Metros	.50	2	4

Source (Authors, 2022)

Mix 1

A mixture of 500 milliliters of water, 500 g of white plaster, ½ meter of ixtle fiber, and 250 g of plastic grinding was made, then they were spread over the mold. Analyzing this test, it was observed that the proportion of water, plaster, and plastic grinding should not be the same since the materials absorb water and the plaster dries quickly without achieving adequate accommodation of the material inside the mold. While the plaster was being mixed, it dried in less than a minute, so when it was poured into the mold it did not have a good consistency, as illustrated in figure 17.

Figure 17 The first test result of the panel

Source (Authors, 2022)

Mix 2

According to what was analyzed in the previous test, a release agent was applied to the wood to get the panel to unmold and the amount of water was increased to 750 milliliters that were added to the mixture made up of plaster 750 g was, 300 g plastic grinding and on this occasion we added 2 meters of ixtle with the intention of giving the panel greater resistance and drilling was done to observe a better homogeneity between the materials, the mixture was more manageable and allowed adequate accommodation inside the mold, The result of this test is displayed in Figure 18.

Figure 18 Placement of the Ixtle fibers in the pouring of the mixture on the wooden mold

Source (Authors, 2022)

Mix 3

A third test was carried out to improve the techniques or methods used in the previous tests, the dimensions are 60 × 60 cm with a thickness of 1.2 cm, the proportion of the materials is made up of 1000 ml of water, 1000 g of plaster, 500 g of plastic grinding, 4 m of ixtle, before this test an improvement was observed in the result of uniformity in the panel, the materials integrate better, and it looks more aesthetically pleasing and thanks to the release agent we were allowed to remove the panel without any complications. The results of this test can be seen in Figure 19.

Figure 19 Third test result

Source (Authors, 2022)

5. Thanks

To the Tecnológico de Estudios Superiores de Jocotitlán for the support received, for the realization of this investigation and experimentation of the prototype.

6. Conclusions

According to the test tests presented above and the panel manufacturing process of the materials and methods, it was found that mixture 3 is the most viable for the manufacturing of the ecological gypsum panel prototype.

However, it was realized that the amount of plastic and plaster depend a lot on their proportions for the malleability of the mixture and adherence. The setting time is very susceptible to climate changes; however, a favorable result was obtained since the materials reacted adequately when mixed.

The ecological plasterboard based on plastic aggregate and ixtle is a solution to current problems of contamination with PET since plastic is increasing day by day and the environmental impact causes serious damage to the lives of all living beings on the planet. The inclusion of plastic in a granulometry state, with the plaster, the ixtle and the recycled paper in the panel was finally a good compositional result in the panel as established in the general objective.

It was found that the project can be a sustainable construction element that replaces the current existing panels to raise awareness about caring for the environment and reduce pollution in the construction industry.

During the development of the investigation, no material similar to that of this proposal was found, which is why it has been considered to be an idea of product innovation since there are only conventional drywall panels and recycled paper without the use of plastic waste or any other type of waste that allows recycling. The materials we use in the panel make it a unique product, making use of natural raw materials from the State of Mexico, in addition to seeing PET recycling as the best alternative to reduce environmental impact.

Knowing the properties of each material used will allow us to investigate more about the results that we could obtain since each characteristic positively contributed to the panel benefits of stability, lightness, and aesthetics. This panel is based on the NMX-C-059-ONNCCE-2013 standard. And based on said standard, tests will be carried out with conventional materials, to observe the behavior of the material during its setting process, it is important to mention that resistance, humidity, and fire tests will be carried out by the standards to specify the functioning test methods. Made for panels which said samples will be tested according to the following standards:

ASTM C-367, Standard Test Methods for Strength Properties of Precast Architectural Acoustical Tiles or Overlay Ceiling Panels, describes the method for establishing the strength properties of acoustical ceiling tiles and panels.

ASTM E-413, Standard Classification for Rating Acoustic Insulation, provides criteria for establishing the ceiling sound transmission (CAC) rating of an acoustical ceiling, similar to the STC ratings for walls.
ASTM C-423, Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method, describes the method for establishing sound absorption coefficient (NRC) values.

ASTM C-635, Standard Specification for the Manufacture, Performance, and Testing of Metal Suspension Systems for Acoustical Tile Ceilings and Overlay Panels, provides classification criteria for load capacity, along with manufacturing tolerance, coatings, and inspection criteria for suspension systems.

Likewise, it is important to mention that the project can be feasible and viable in the field of construction, a sustainable construction element as an alternative to the current existing panels to raise awareness about caring for the environment and reduce the environmental impacts that the construction industry generates, nowadays. Therefore, the regulations were met in the tests carried out.

This panel is a product with radical innovation since there are only conventional plasterboard and cardboard panels without the use of plastic waste or any other type of waste that allows recycling. The materials that were used in the panel of this research make it a unique product, in addition to seeing the recycling of PET as the best alternative to reduce the environmental impact. It is important to mention that innovation allows the generation of new knowledge and proposes solutions to problems that can be related to multiple aspects, which, in the medium and long term, can mean economic growth, improvement in productivity, and the social development of a nation.

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